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THE BULLETIN IN WAR TIME

The Jesuit Science Bulletin, like its present Editor, has come of age since the last war. There is, therefore, no precedent to guide it in this emergency in which it finds itself, and in which it will, perhaps, find itself for some time to come. And now, when plans for united action are being formulated and carried out with almost unbelievable detail, it seems that we too, should not drift through such a splendid opportunity to write first hand the history of the Society's achievements. The purposes of the BULLETIN have been formulated at frequent intervals by its Editors. The chief of these are, it seems, to afford a medium of contact for all ours working in science, and to give the younger men of the Society an opportunity to feel, in familiar surroundings, the first thrill of publication. That the BULLETIN has achieved the second end, a mere perusal of its pages will testify. Perhaps, as a medium of contact and exchange of ideas, it has not always been utilized with the efficiency within its possibilities. Now during an abnormal period, all our men of science are even more than normally busy. New courses are being introduced, others are being rearranged, schedules are being disrupted for a variety of reasons, detail work has increased, and to add to the complication, holidays have either been cut to a minimum or abolished altogether. It would be a natural reaction to consider the added strain on one's time sufficient reason for neglecting our common interest as mentioned above. Yet under present day circumstances we need probably more contact with each other, so that all may have the advantages of the consideration and experience each has had in meeting the present needs. Our scholastics in science are interested in the work which is now being done, and in which they will soon be taking their part. If they have the opportunity to read and study the methods of meeting the problems in our various houses, their interest and enthusiasm will be increased and they will be better equipped for participation.

It is unfortunate that during the last war the BULLETIN did not exist to record the work done by individual Jesuit Scientists and the all-important routine work which was the part of practically all our schools. With an opportunity like the BULLETIN at hand, such a record should not be missing when the present emergency passes. On the other hand, a record of the changes made in our normal science courses, adaptations of personnel, and the actual work done, insofar as its nature will permit publication, would be worthwhile achievement for the BULLETIN, and a valuable source of history of our schools and especially their science departments. It seems wise to give some consideration to the BULLETIN from these view points, so that it may be a vital organ of our work, fulfilling now, even more than in peace time, the purpose of its founders. We should not, in spite of the ever increasing demands on our time, allow the BULLETIN to fade into the background, during a period of such increased and specialized activity.

SCIENCE AND PHILOSOPHY

ON "FINALITY IN PHYSICS".

PETER MUELLER, S.J.

Finality is a strictly philosophical concept; and as such, it is said, it ought to be banned from the realm of exact sciences. Physics and Chemistry are concerned only with the causa efficiens,—if, indeed, they are concerned with causes at all, and are not confined to mere conditions and their functional relations. In these few words, the general attitude of scientists of today may be well summed up. Max Planck, however, terms that attitude a "short-sighted positivism", through which a scientist deprives himself of the possibility of a deeper understanding of natural phenomena. From the standpoint of our own philosophy, it seems to me, we could only welcome every possibility of a more close cooperation between the two realms of knowledge. It is the intention of this article to show by an example, that and how such cooperation seems to be possible.

In 1615, Snellius discovered what is today known as the law of refraction:

$$\frac{\sin\alpha}{\sin B} = \frac{c_1}{c_2} = n.$$

This law as such, and as discovered by Snellius is a purely experimental law; it, therefore, does not give any reason, why the ratio of angle of incidence and of angle of refraction is a constant for a certain system (e.g. "air-water"), but it just says that one ratio is equal to the other, viz. to that of the two velocities of light in the two media. But if we assume, as Leibniz did, that a light ray takes the shortest possible path between two points in the different media, i.e. that one which takes the shortest possible time, we'll get exactly the law of refraction, and that by a purely mathematical deduction.

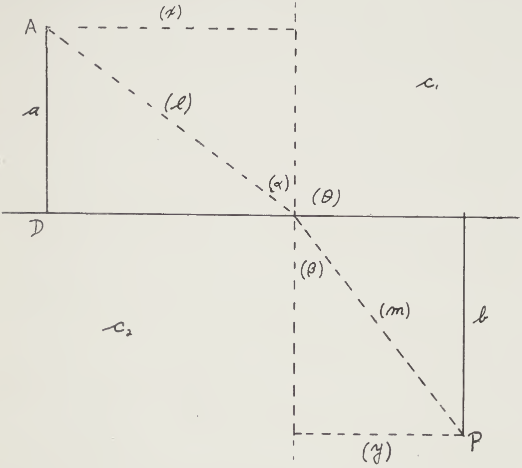
Let c_1 and c_2 be the velocities of light in the two media;

A and P two points of a ray, with the coordinates: $A(a/x)$, $P(b/y)$, a and b being known.

x and y unknown, but their sum known: $(x+y)=DE$.

(*In the fig.*, the letters in brackets and the dotted lines indicate unknowns.)

The question is: Which path does the ray take going from A to P, if it chooses the one of minimum time?



From commonly known formulæ, we have the following equations:

$$t = \frac{s}{c}\,; \qquad c = c_1 \text{ between A and O,}$$

$$s = l + m \qquad c = c_2 \text{ between O and P.}$$

$$(1) \qquad t = \frac{l}{c_1} + \frac{m}{c_2} = \frac{1}{c_1}\sqrt{a^2+x^2} + \frac{1}{c_2}\sqrt{b^2+y^2}\,;$$

Now, this time is supposed to be a minimum, i.e. its derivative is zero:

$$(2) \qquad dt = \frac{dt}{dx}dx + \frac{dt}{dy}dy = O;$$

$$dt = \frac{1}{c_1}\frac{xdx}{\sqrt{a^2+x^2}} + \frac{1}{c_2}\frac{ydy}{\sqrt{b^2+y^2}} = O;$$

$$\text{i.e.} \qquad \frac{1}{c_1}\frac{xdx}{\sqrt{a^2+x^2}} = -\frac{1}{c_2}\frac{ydy}{\sqrt{b^2+y^2}}\,;$$

Moreover, as $(x+y)=DE$, a constant, the derivative of this sum will be zero: $dx+dy=O$, i.e. $dy=-dx$; and the last equation may be written as:

$$\frac{1}{c_1}\frac{x}{\sqrt{a^2+x^2}}=\frac{1}{c_2}\frac{y}{\sqrt{b^2+y^2}};$$

$$\frac{1}{c_1}\frac{x}{l}=\frac{1}{c_2}\frac{y}{m};$$

But $\frac{x}{l}=\sin\alpha$, and $\frac{y}{m}=\sin B$, as it is easily seen in our fig. Therefore,

$$\boxed{\frac{\sin\alpha}{\sin B}=\frac{c_1}{c_2};}$$

i.e. by means of a distinctly teleological assumption, put in mathematical form, we have reached the same law that was discovered experimentally by Snellius.

Max Planck, in an article on "the miracle of the regularity of nature"[1] adds the following remarks: "The refraction, therefore, is completely determined by the simple law which runs as follows: Amongst all possible paths between a star and the eye of an observer the light takes just that one which needs the shortest possible time, i.e. the photons behave like rational beings, choosing from amongst all possible curves, at their disposal, always the one on which they will reach the goal in the shortest possible time". Then the author goes on to show that this theorem may be generalized, and that it can be stated: From amongst all possible processes through which a system is turned from one state into another during a certain time the one actually followed will be always that in which the integral of a certain magnitude,—the so-called function of Lagrange—, taken over the given interval of time, is a minimum.

Planck, then, concludes with the following words: "No wonder, indeed, that the discovery of such a law made Leibniz, the author, and Maupertuis, his successor, quite enthusiastic; for these men were convinced that they had a palpable sign of the ruling of a higher Reason, governing nature omnipotently. Indeed, by this principle, quite a new idea is introduced into the notion of causality: The causa efficiens, which acts from the present into the future and through which the later states appear to be conditioned by the earlier ones, is joined by the causa finalis which, vice versa, makes the future, i.e. a certain end, aimed at, the condition of the course of the processses, leading to that

1. This article appeared in a book "Die Natur, Das Wunder Gottes" (Nature, the miracle of God), Berlin, 1938; other contributors are: Heisenberg, Driesch von Uexkuell, etc.

end. As long as one restricts oneself to the realm of physics, both considerations are but different mathematical forms, concerned with the same thing; and it would be useless to ask, which one of them comes nearer to the truth. . . . . But, here, we are concerned with more general problems. All we want to do is, to state that theoretical physics, in its historical development, yielded a formulation of physical causality which has a distinctly teleological note. But, for all that, nothing new or contradictory has been introduced in respect to the regularity of nature. Though different in form, it is an equally valid way of reasoning. . . . In any case, according to all teachings, in the whole realm of nature, there is to be observed a definite regularity which, though independent from the existence of thinking men, nevertheless, as far as approachable by means of our senses, allows itself to be formulated in a way which betrays teleologiacal action".

Thus far Max Planck. We thought it worthwhile, to quote the words of this preeminent physicist of today's literally, as far as a translation permits; the more so, as his ideas in this matter are by no means common property in contemporary science.

The behaviour of light, as explained, seems to be a perfect example of true finality in the inorganic world, illustrated by the physical method itself.

CHEMISTRY

APPLICATION OF THE ISOTHERMAL DISTILLATION METHOD FOR HIGH MOLECULAR WEIGHTS

Richard B. Schmitt, S.J.

The isolation of a crude but highly bactericidal substance of a non-protein nature from cultures of an aerobic sporulating bacillus was recently announced by Dubos and Cattaneo (1). From this substance, later referred to as tyrothricin, two crystalline compounds, gramicidin and tyrocidine hydrochloride (2,3) were obtained. Both compounds were found to be highly bactericidal, for Gram-positive microorganisms. (Those bacteria which retain the Gram stain.)

Gramicidin was isolated from tyrothricin by a prolonged extraction with absolute ether. This observation is somewhat unexpected, inasmuch as it has been demonstrated that gramicidin is a ploypeptide of high molecular weight.

A determination of the molecular weight was made by a modification of the isothermal distillation method of Barger, Niederl and collaborators (4). In the determination under consideration, 82.77 mg of a carefully prepared, rigorously dried sample of gramicidin were weighed into the right-hand limb of a V-tube, and 4.119 mg. of a sample of pure 2, 3-dimethyl-1, 4-napthoquinone into the left-hand limb. The gas had been carefully discharged from the entire vessel before the introduction of these materials, and methyl alcohol (over a drying agent) was vacuum-distilled into the two limbs of the vessel, thus forming the solutions. These were frozen at dry ice temperature, and the vessel sealed under a vacuum.

In consideration of the serious errors which would accrue as a result of any appreciable quantity of low molecular weight impurities, a rigorous technique, designed to avoid the presence of water or of atmospheric gases, was used at every stage of the filling operation.

The quantities of methanol introduced into the right and left-hand limbs were respectively 6.78 and 4.51 ml. The vapor pressure of the solvent from the two solutions thus formed is the same, in case the molecular weight of the unknown is 2500. (A preliminary diffusion experiment in which n-butanol was used as solvent, had indicated a value of the molecular weight in the range of 2500 to 4500.) The closed system was kept at a constant temperature (24°), and the transfer of the solvent measured from time to time by observing the volume of the solution in each of the two limbs. The results are shown in the Table I.

A graph of the results indicates that the distillation proceeds uniformly in time until the 70th day. Thereafter there is no distillation, indicating that the two resultant solutions are in equilibrium with respect to the vapor pressure of the solvent. Accordingly, from the data above, this condition of equilibrium indicates for the molecular weight of gramicidin a value of 3100.

It is interesting to note that the analytical results of gramicidin flavianate are in agreement with this value.

Table I.

Molecular weight of gramicidin as retermined by isothermal distillation.

Days	Volume	Right limb	kV (left limb)*	Apparent
0	Left limb	ml	ml	Mol. Wt.
13	ml	6.78	0.0	(2500)
44	4.51	6.70	+0.07	(2800)
62	4.58	6.49	+0.30	3100
73	4.81	6.25	+0.52	3100
91	5.03	6.20	+0.59	3100
105	5.10	6.18	+0.59	
	5.10	6.18	+0.61	
	5.12			

The parentheses indicate non-equilibrium values.

*kV is the volume change in the left limb due to distillation of solven from the right limb.

On the assumption that 1 molecule of gramicidin of flavianic acid, the sulfur content (0.97%) indicates a molecular weight of 2986±300; the carbon ratio between gramicidin flavianate and its individual components places the value at 3036±300.

(As recorded in: The Journal of Biological Chemistry, Vol. 141, No. 1, October 1941.)

BIBLIOGRAPHY

1. Dubos, R. J., and Cattaneo, C. J., Exp. Med., 70, 249 (1939).

2. Hotchkiss, R. D., and Dubos, R. J., J. Biol. Chem., 136, 803 (1940).

3. Hotchkiss, R. D., and Dubos, R. J., J. Biol. Chem., 132, 791 (1940).

4. Niederl, J. B., Micromethods Org. Elem. Anal. (Wiley & Sons.) p. 230 to 237, (1942).

SCIENTIFIC ADVANCE IN 1941

Richard B. Schmitt, S.J.

The enumeration of the high lights in scientific progress, may be of interest to the philosopher and other students. It is perfectly clear, we cannot record, in this short article, all the progress in scientific endeavour; that would be impossible. However, the mention of outstanding and evident progress in the regular yearly program, usually due to careful and laborious research, might be helpful to the busy non-science student.

We might begin by stating, that starch was produced synthetically, a significant and important achievement. The sulfa compounds were found to act similar to hormones on the growth of plants. Gramicidin, penicillin and bacteriophage were tested clinically and found to be the most powerful germ destroyers ever known. A new extract was prepared, which may some day give definite control of blood pressure. Parabenzoic acid was tested on men and women and found to restore prematurely gray hair to its natural color. Astronomers have found new methods for determining the temperature of the corona of the sun. A gas composed of carbon and hydrogen was found in interstellar space.

Physicists agree that the primary cosmic rays are *particles*; that they originate in outer space, collide with atoms in the upper air and generate or produce other rays designated as "secondary". But what are these particles? Certainly not *electrons,* but heavier protons or hydrogen nuclei; at least this is the opinion or theory of Dr. A. H. Compton (Chicago Univ.) who bases his conclusions on the fact that primary cosmic rays can penetrate seven inches of lead, whereas four inches is about the limit for electrons.

Dr. R. A. Millikan (California Institute of Technology) holds the opinion that, primary cosmic rays are *electrons* produced by atoms that annihilate themselves in space. The primary rays, he holds, have an energy of between two and fifteen billion electron volts. The action on the nuclei in the upper air, produces mesotrons, these are found between protons and electrons, and carry the energy farther than the electrons could themselves.

To prove this theory, Dr. Millikan made observations in India, near the equator, and in the United States at higher altitudes. He holds therefore, that the earth is a big magnet, that only the more powerful primary rays can penetrate to the equator.

The cyclotron at the University of California has produced energies as high as 96,000,000 volts. Another cyclotron succeeded in changing mercury into *gold* and then *platinum*; however in infinitesimal amounts. Dr. A. C. Helmholtz got a form of cadmium, which remained radioactive for weeks.

To the long list of sulfa drugs, two new ones were added. They are: sulfadiazine and sulfaguanidine. The first is used in pneumonia, the second in disposing of bacillary dysentery.

The outstanding accomplishment of chemical and engineering chemistry was on January 21, 1941, when the new plant of the Dow Chemical Co., at Freeport, Texas produced the first commercial ingot of any metal taken from sea water in the history of the world. At the end of the past year, 54,000,000 lbs., of magnesium metal was taken from the sea. The production of the present year will probably exceed 125,000,000 lbs. Dow's production is going into defense, mostly aircraft parts. When one considers that as much as 1,000 lbs. of magnesium may enter into the manufacture of a single plane, and that we are scheduled to be turning out 4,000 planes a month, in 1942, it is apparent that the aviation industry's demands for magnesium are reaching vast proportions. Another happy phase of the picture is this: the price of magnesium metal dropped from $5.00 a pound to 22½ cents a pound. It is also worthy of note to realize the purity of the metal from this particular process (which is electrolytic), the fused metal rising to the top cell bath, has an average purity of 99.8%.

So far, 29 varieties of synthetic rubber have been studied. Current production for general purposes, synthetic rubber supplies about 3% of the crude consumption. The output in 1942 should be at least 15% the normal requirements; by the end of the year the yield will be about 40,000 tons. The methods that are now yielding appreciable amounts are the neoprene, the butadiene, and the polysulphide types. The Goodrich Co., is manufacturing from 6 to 18 tons a day; its resistance to aging is described as superior to natural rubber.

Television in natural colors was demonstrated in London by John L. Baird, a pioneer television expert.

For making shells explode in munitions and in industry, mercury fulminate was the detonator used for many years. Because of the huge demand for our national defense program, there was not enough mercury available, so our American chemists got busy and solved the problem by making a substitute, with the same properties at mercury fulminate; the new compound is made of lead and nitrogen, the formula is PbN_6. And this problem was solved in less than three months.

Chemistry Marches ON.

MATHEMATICS

ON MINIMIZING CERTAIN FUNCTIONS OF TRIANGULAR NUMBERS*

Rev. Edward C. Phillips, S.J.

The particular kind of function under consideration in this paper arises from the solution of the following mathematical recreation:

> GIVEN an equilateral triangle composed of $n(n+1)/2$ coins, to invert the triangle, i.e. to construct a new figure with the apex pointing in the opposite direction, by moving *the least possible number* of coins.

If n is 2, we have three coins disposed as in figure 1 (a) and by moving the apex coin from above the base to below the base we have performed the required inversion with *one* coin, which is evidently the minimum number, and we have the figure 1 (b) in which the coin that was moved is represented by an x, the others being represented by o's. There is a second way of making the inversion with the movement of a single coin, indicated in Figure 1 (c).

Figure 1.

o	o o	x o	o	x o x	o o x
o o	x	o	o o	o o	o o
			o o o	o	x
(a)	(b)	(c)	(d)	(e)	(f)

Figure 1 (e) and 1(f) show how a triangle of base 3, with six coins, can be inverted in two different ways, each involving only 2 coins which is the minimum number for this case. In figure 2 there are given four different ways of inverting the triangle of ten coins, with base 4; we will here represent the coins by numbers, those representing the displaced coins in bold face type so as to indicate more clearly which coins were moved and the new positions they hold, the first of the five triangles being the original one with its apex upwards.

*Paper read at the fall meeting of the Md.-D.C.-Va. Section of the Math. Assoc. of America, December 6, 1941.

Figure 2.

```
      1              7  1  8  10         7  2  3  10
     2  3              2  3  4             4  5  6
    4  5  6              5  6                8  9
   7  8  9  10            9                   1
      (a)                (b)                 (c)
              4  5  6  7           7  8  9  10
               8  9  10              4  5  6
                 2  3                  2  3
                   1                    1
                  (d)                  (e)
```

In (b) the new base was established along the top line of the original triangle, and coins numbered 4, 7, 8, 10, four in all, were moved.

In (c) the new base is along the second line; coins 1, 7, 10, or three in all, were moved.

In (d) the new base is on the third line, the four coins 1, 2, 3, 7 having been moved.

In (e) the old base was retained and all above it, six in all, had to be moved.

This case brings out a fact which we readily see is universal, namely that the number of coins to be moved varies as we choose different lines of the triangle along which to constitute the new base: if we call the serial number of this line, starting from the apex downwards, x; the number of coins to be moved N; then N is a function of x. In the case of a triangle with a base of four coins, containing $4(5)/2$ or ten coins in all, we have the following relations: For $x=1$, $N=4$; for $x=2$, $N=3$; for $x=3$, $N=4$; and for $x=4$, $N=6$. The minimum in this case is 3.

Since we wish to obtain a general solution for triangles of any size, the above method of representation, which we may call pictorial, is not convenient; the following numerical method has been found very useful. We represent the original triangle by the series of integers placed one below the other, beginning with unity and ending with n or the number of coins in the base; this column of numbers then represents the triangle by indicating the number of coins in each successive line or row. The movement of a coin or several coins from one row to another will be represented by subtracting the number moved from the serial number of the given row and adding the same number to the serial number of the row to which the coins have been moved. The cases of Figure 2 will then be represented thus; the numbers in the third column representing the new resultant triangle:

Figure 3.

$1+3=4$	$1-1=0$	$1-1=0$	$1-1=0$
$2+1=3$	$2+2=4$	$2-2=0$	$2-2=0$
$3-1=2$	$3\quad=3$	$3+1=4$	$3-3=0$
$4-3=1$	$4-2=2$	$4-1=3$	$4\quad=4$
	$0+1=1$	$0+2=2$	$0+3=3$
		$0+1=1$	$0+2=2$
(b)	(c)	(d)	$0+1=1$
			(e)

Since the first and the third column in each set represent the original and the inverted triangle respectively, they consist of the same arithmetic series, 1, 2, 3, . . . up to n, in descending order and ascending order respectively; the sum of each is therefore the same triangular number $n(n+1)/2$. The second column of each set also consists of two, or four, similarly related arithmetic series of which half are affected with the plus sign and the other half with the minus sign. The sum of all the numbers with the same sign is equal to the total number of coins moved. By using this method in contracted form we can easily represent in a manageable way the inversion of any triangle, however large. Take for example the triangle with a base of 54 coins, containing therefore 54x55/2 or 1485 coins in all. We give in Figure 4 this numerical method of representation for two inversions, in the first of which we have taken the 17th line as the position of the new base, and in the second the 18th line:

Figure 4.

1	−1	0
2	−2	0
16	−16	0
17	+37	54
18	+35	53
19	+33	52
34	+ 3	37
35	+ 1	36
36	− 1	35
37	− 3	34
38	− 5	33
52	−33	19
53	−35	18
54	−37	17
0	+16	16
0	+15	15
0	+ 2	2
0	+ 1	1

(a)

1	−1	0
2	−2	0
16	−16	0
17	−17	0
18	+36	54
19	+34	53
34	+ 4	38
35	+ 2	37
36	0	36
37	− 2	35
38	− 4	34
52	−32	20
53	−34	19
54	−36	18
0	+17	17
0	+16	16
0	+ 3	3
0	+ 2	2
0	+ 1	1

(b)

The different arithmetical series have been separated by horizontal lines. In the first inversion (a) we have one type of series in the central portion, in which all the numbers are odd and in (b) we have the other type in which the central series are all even numbers: these two types will follow each other alternately as we change the position of the new base step by step. In (a) we can easily see that the coins moved consist of the two

series 1, 2, 3, . . . 16 which equals 16x17/2 or 136
and 1, 3, 5, . . . 37 which equals 38x38/4 or 361
and hence the total number of coins moved is 497

In (b) the two series indicating the number of coins moved are:
1, 2, 3, ... to 17, which equals 17x18/2 or 153
and 2, 4, 6, ... to 36, which equals 18x19 or 342
and hence the total of coins moved is 495

If we move the new base down one more line, to the 19th, the number of coins moved will be also 495: whilst the new base being on the 20th line requires 496 coins to be moved, and the number increases for every move downwards after this. Hence in this case the minimum solution is 495, which is one third of the total number of coins, 1485. In fact in every case so far studied the minimum number has been 1/3 of the total, or as in the case of 10 coins, the integral portion of one third of the total. This suggests that the solution is always one third of the total (or of the total less one).* We desire however a general proof of this supposition.

One method would be get a sufficient number of particular values from which to derive the general solution by the method of indeterminate coefficients. Another method would be to derive the general expression for the series involved, in terms of n, i.e. the number of coins in the base of the given triangle, and x, i.e. the line along which the new base of the inverted triangle is placed. We will use this second method.

If the new base is along the line x spaces from the apex, the partial triangle above this line, which we will have to move to the bottom of our new figure, will evidently have $(x-1)$ coins in its base and the total number of coins in this partial triangle will be $x(x-1)/2$. Now the second series, corresponding to the central series in (a) and (b) for the case of a triangle of a base of 54 coins, will be of the first type (all odd numbers) or of the second type (all even) numbers according as $(n-x)$ is odd or even. Since we must move up from the lowest line of the original triangle $(n-x)$ coins so as to make the xth. line equal to n and at the same time reduce the base line of the original triangle to x coins, our series in either case begins with the number $(n-x)$; if this is odd, the last number of the series (i.e. the smallest one) will

* Note. All triangular numbers are of the form 3p or $(3p+1)$, but never $(3p+2)$.

be 1: if $(n-x)$ is even, then the series begins with an even number and ends with 2.

The sum of the series of odd numbers from 1 to m is $(m+1)^2/4$; and the sum of the series of even numbers from 2 to m is $m(m+2)/4$. Hence the total number of coins to be moved in the two types of inversion are:

$$No=(x-1)x/2+(n-x+1)^2/4 \text{ if } (n-x) \text{ is odd; and}$$
$$Ne=(x-1)x/2+(n-x)(n-x+2)/4 \text{ if } (n-x) \text{ is even.}$$

Expanding these expressions and arranging them in order of ascending powers of x our two equations become (placing y for N)

$$y_o=3x^2/4-x(n+2)/2+(n+1)^2/4 \qquad \text{for } (n-x) \text{ odd, and}$$
$$y_e=3x^2/4-x(n+2)/2+n(n+2)/4 \qquad \text{for } (n-x) \text{ even.}$$

We may note here that from the geometric point of view these are the equations of two parabolas: both have the same axis, namely the line $x=(n+2)/3$; the constant terms differ by the quantity $\frac{1}{4}$ which is independent of n: the curve for N_o could be obtained from the other one by simply moving it upwards along its axis one quarter of the unit of measure of the coordinate system.

The above equations give us the complete solution of the first part of our problem, namely to determine the number of coins that have to be moved to make any arbitrarily chosen inversion. The second part of the problem requires us to find the *minimum integral* values of N or y given by these functions. The problem cannot be solved by the usual method of the differential calculus, because this supposes the function to be continuous, whereas our values of both x and y are restricted to integers. Moreover *successive* solutions with integral values for x and y do not belong to a single equation but the first of each successive pair (x, y) belongs to one of the equations and the second pair belongs to the other equation: hence to obtain the *integral increment* (of No) for unit increment in x, we must replace $(x+1)$ for x in Ne (not in No) and take the difference. Calling this increment Do,e we have

$$Do,e=(3x-n-1)/2$$

or, starting with Ne and going to the succeeding No, we have

$$De,o=(3x-n)/2.$$

For the firse case, it is clear that the increment Do,e will be negative as long as 3x is less than $(n+1)$ and it will be positive when x is greater than $(n+1)$. Likewise in the second case, the increment De,o will be negative when x is less than n and positive when x is greater than n.

There are two distinct cases to be considered. First, suppose that neither n nor $(n+1)$ is an exact multiple of three, then it is clear that

as we move the new base from the line given by the integral portion of $n/3$ or $(n+1)/3$, to the next lower line, the number of coins to be moved will decrease since the increment is negative; but as we move the new base down further the number of coins will increase since now the increment is positive: therefore the unique minimum solution is had when the new base is placed on the line of the original triangle for which x is one unit greater than the integral part of $n/3$, or of $(n+1)/3$ as the case may be, and this value in both cases is equal to $(n+2)/3$ which *is* an integer.

Secondly, suppose that n or $(n+1)$ is an integral multiple of 3; then Do,e or else De,o becomes *zero* for $x=n/3$, if that is integral, or for $(n+1)/3$ when this is integral. Now, when the "increment" is zero, the value of No or Ne, as the case may be, does not change as we lower the new base line from the line $n/3$ to the next line $n/3$ plus 1 (or from $(n+1)/3$ to $(n+1)/3$ plus 1). However as the increment changes from negative to positive as we pass through this double value of x, the value of N in this double position is less than for any preceding position of the new base and also for any succeeding position; and hence there are for the cases of $n/3$ or $(n+1)/3$ being integral, two equal minimum solutions.

A few particular examples will illustrate the various cases. First, take $n=4$: then neither $4/3$ nor $5/3$ is integral and there is only one minimum solution given by $x=2$, namely one unit greater than the integral portion of $4/3$ or of $5/3$, and the minimum solution is had when the new base is placed on the second line of the original triangle, as we discovered experimentally at the beginning of this paper. (cf. Fig. 2(c)). If we take the cases for n equal to 2 and n equal 3, $(n+1)/3$ in the first case and $n/3$ in the second case are integral, namely 1. Hence in these two cases there is no change in the value of N as we move the new base from the first line to the second line of the original triangle, and we have two minimum solutions in each case. Cf. again the experimental determinations given in Fig. 1 (b) and (c) for $n=2$, and Fig. 1 (e) and (f) for $n=3$.

If we seek the *absolute* minimum of No and Ne considered as continuous functions of x, we find that for both forms of the function this absolute minimum is given by $x=(n+2)/3$. If this is integral, then the *absolute* minimum is also an *integral* minimum, because the value of Ne given by putting this value of x in its equation is $3p(p-1)/2$, where p is defined by the equation $p=(n+2)/3$, and if p is odd $(p-1)$ is even and therefore the produce $p(p-1)$ is always divisible by 2 no matter what integer p may be. As this is the absolute minimum of the function there cannot be any other solution, and there is only one minimum inversion. This is simply a confirmation of what has already been proved namely that when *neither* $n/3$ *nor* $(n+1)/3$ is integral there is only one solution—for these two condi-

tions necessarily involve and are involved by the other condition, namely that $(n+2)/3$ *is* integral.

Placing the critical values of x, namely $n/3$, $(n+1)/3$ or $(n+2)/3$ according to which one is integral, in the corresponding equations for N, we find the minimum values of N, which we will call M, to be

a) when $n/3$ is an integer p: $M=n(n+1)/6=p(3p+1)/2$

b) when $(n+1)/3$ is an integer p: $M=(n+1)n/6=p(3p-1)/2$

c) when $(n+2)/3$ is an integer p: $M=(n+2)(n-1)/6=3p(p-1)/2$

Since the total number of coins in the original triangle with base n, is $n(n+1)/2$, it is clear that in cases a) and b) the minimum solution requires that exactly one third of the coins be moved. In case c) we can see that $(n+2)(n-1)$ equals n^2+n-2 or $n(n+1)-2$ and one half of this is the total number of coins less one; therefore in this case the number to be moved is again one third of the total number of coins less one, or the integral portion of one third of the total number.

Examining further the above three values of M as expressed in terms of p, we find that for case c), namely the case with a unique minimum solution, the number of coins moved is three times the triangular number $p(p-1)/2$, so that the coins moved may be arranged in three *equal* triangles. And in fact for this case the solution has full triple symmetry as shown below for the particular triangle with a base of seven coins.

In cases a) and b) we can also break up M into three triangular numbers, but not all three will be equal: we have

$$(3p^2+p)/2=(2p^2+2p+p^2-p)/2=2p(p+1)/2+p(p-1)/2$$

and $$(3p^2-p)/2=(2p^2-2p+p^2+p)/2=2p(p-1)/2+p(p+1)/2$$

so that the number of coins to be moved breaks up into two triangular numbers of base p and one of base $(p-1)$; or else two of base $(p-1)$ and one of base p. These are represented below by the particular solutions of triangles with original bases of 6 and 5 respectively.

In these figures the dots indicate the original positions of the coins that are moved; the x's the positions to which they are moved and the o's the positions of the coins which remain unchanged.

n=5	n=6	n=7
.	.	.
. .	x x o o x x	. .
x o o o x	x o o o x	x x o o o x x
o o o o	o o o o	x o o o o x
. o o o .	. o o o .	o o o o o
x x	. . o o . .	. o o o o .
x	.	. . o o o . .
		x x
		x

PHYSICS

NUCLEAR FISSION AND THE TRANSURANIC ELEMENTS

John J. McCarthy, S.J.

For the past two years the words nuclear fission, transuranic elements, chain reactions, uranium as a source of enormous atomic energy have appeared frequently in the press, science journals and the reports from science meetings and research laboratories. This phase of modern science is comparatively recent and the only information available is that which can be culled from the monthly scientific journals. The writer knows of no text-books which have been written on the subject, at least from an elementary point of view. The purpose of this paper is to acquaint the reader with the elementary facts of nuclear fission, its interesting history and discovery, the theory as it has been developed thus far, an explanation of the terms used in its discussion, its progress up to this time and its practical applications.

Nuclear fission was discovered by Hahn and Strassmann in January, 1939 and with this discovery one of the most interesting eras in modern physics was closed and a new one opened. The search for transuranic elements had ended not in the discovery of a new element but in the rediscovery of old ones. In 1934, shortly after the discovery of the neutron, Fermi realized that the bombardment of Uranium with neutrons might lead to the production of atoms of atomic number 93 or higher by successive beta-disintegrations. All radioactive substances, whether natural or artificial, disintegrate into more stable substances by the ejection of negative beta-particles. The ejection of a beta-particle produces an atom with the atomic number increased by one. It was to be expected that uranium, bombarded with neutrons, would become unstable and by beta-disintegration produce atoms of atomic number 93 or higher. Several beta activities were actually found. Chemical tests showed that they were not isotopes of any elements from radon to uranium inclusive. The only remaining hypothesis was that they were activities of transuranic elements having atomic numbers of 93 or higher. It is interesting to note that the solution of the problem was offered immediately by Noddack. She criticized Fermi's conclusions on chemical grounds, contending that certainty of proof of the existence of transuranic elements could be had only by more elaborate tests which would exclude all known elements. She suggested that the bombarded nucleus might have split up into elements of lower atomic number which, in fact, has turned out to be the case. Apparently, it was rejected as an improbable alternative wherever considered, because it seems to have had no influence on the subsequent course of events.

For the next four years physicists worked on the problem of the apparent transuranic elements and several, particularly Curie and Savitch, came very close to making the great discovery. In 1938, Hahn and Strassmann bombarded uranium and detected several activities which from their chemical characteristics, they attributed to isotopes of radium. The reason for attributing the activities to radium and not to transuranic substances was the fact that the activities were precipitated with barium as a carrier. A glance at the periodic table will recall that barium and radium are in the same family. The activities in question were so similar to barium chemically that barium and radium were the only two elements to which they might be ascribed. In trying to prove that these atoms were without a doubt isotopes of radium they proved to their surprise that they were certainly isotopes of barium. Thus, almost by accident, the phenomenon of fission was discovered. Uranium bombarded with neutrons, instead of producing a new element by beta-disintegration, had actually split into two parts and formed two well known elements in the middle of the periodic table.

Before discussing the theory of fission let us recall a few salient notions of the nucleus as we know it today. The outstanding facts are these. Nuclear forces set in when the particles are about 2×10^{-13} cm. apart. They are large and of short range. They bind protons with fifty times the energy of their electrostatic repulsion at this distance. Unlike the Coulomb force, they fall off, not gradually with distance of separation but abruptly within a short distance. Two protons 1.3×10^{13} cm. apart experience strong nuclear attraction; at three times that distance apart they experience only the Coulomb repulsion of their positive charges. In nuclei of the lighter elements, the nuclear forces far exceed the forces of the electrostatic repulsion of the protons and the nucleus remains stable. However, as the atomic number increases, that is, as we approach the heavier elements, the electrostatic repulsion of the charged particles becomes greater due to the large number of protons and it is easy to conceive of a condition where these forces equal or overbalance the nuclear forces so that the nucleus becomes unstable or flies apart of its own accord. Obviously, nuclei of the latter type would be non-existent. The above hypothesis forms the basis of the theoretical considerations of Meitner and Frisch and later of Bhor and Wheeler in an attempt to explain the phenomenon of fission and the absence of transuranic elements.

Modern theory draws the analogy between the nucleus and a drop of liquid. The nuclear forces of short range are analogous to the cohesive forces between the atoms of a drop of liquid and tend to produce similar effects of surface tension in the nucleus. The electrostatic energy of repulsion of protons tends to produce the opposite effect. The spherical shape, which gives the minimum surface for a given volume, is for a liquid the one of stable equilibrium. This is

a stable state for the nuclear forces and an unstable one for the electrostatic forces. The actual nucleus will be stable as long as the sum of the surface energy and the electrostatic energy has a minimum for the spherical state. With increasing size and charge of the nucleus this minimum becomes flatter and would be expected to disappear altogether for some critical value of the atomic number. Nuclei of greater atomic number would immediately break apart. Meitner and Frisch estimated that this would occur for value of atomic number close to 100. Since the uranium nucleus lies close to this limit of complete instability, it seems reasonable that it should have only slight stability of form and be likely to divide into two nuclei upon receiving a moderate energy of excitation.

Let us take, for sake of illustration and clarity, an actual case of fission. A sample of uranium is bombarded by neutrons. A neutron enters the nucleus of a uranium atom and transmits its energy to the particles contained therein. This energy is not transmitted to any particular particle but to the nucleus as a whole. Just as heat raises the temperature of a drop of water and increases the velocity of the molecules, so in an analogous manner, the bombarding neutron raises the "pseudo-temperature" of the uranium nucleus and leaves it in a highly excited and unstable state. If the energy of excitation is not sufficient to cause fission, the excess energy is "boiled off" in the form of a neutron or radiation. If the energy is sufficient, the nucleus fissures and breaks into two parts. Assume that the U nucleus with a net charge of +92 is to split into two nuclei having charges +54 and +38, respectively. (Xe and Sr) The heaviest stable atoms of these two elements are Xe^{136} and Sr^{88}, which have a total mass of 224 instead of the 239 of the splitting U nucleus. There is an excess of 15 neutrons to be divided between the two resulting nuclei. The immediate products of the fission might be something like ${}_{54}Xe^{140}$ and ${}_{38}Sr^{99}$. This particular division is the one which, for the assumed charges of the fragments, most nearly preserves in both of them the neutron/proton ratio of the original U nucleus. It is not meant to imply, however, that there is any good reason for believing that the splitting will necessarily preserve this ratio. These nuclei are unstable because they contain an excess of neutrons. Both nuclei proceed to find a stable atom with mass 140 and 99 respectively. According to our latest beta-ray theory, the neutron changes to a proton and emits an electron. Hence the Xe nucleus would undergo four successive beta-disintegrations to become stable ${}_{58}Ce^{140}$ and the Sr would undergo six to become stable ${}_{44}Ru^{99}$. The disintegration series is as follows:

$${}_{54}Xe^{140} \rightarrow {}_{55}Cs^{140} \rightarrow {}_{56}Ba^{140} \rightarrow {}_{57}La^{140} \rightarrow {}_{58}Ce^{140}$$

$${}_{38}Sr^{99} \rightarrow {}_{39}Y^{99} \rightarrow {}_{40}Zr^{99} \rightarrow {}_{41}Nb^{99} \rightarrow {}_{42}Mo^{99} \rightarrow {}_{43}Ma^{99} \rightarrow {}_{44}Ru^{99}$$

This is an example of fast neutron fission which, according to present theory, involves the uranium isotope of atomic weight 238. An example of fission by thermal or slow neutrons which has been ascribed to the uranium isotope of atomic weight 235 is as follows. Upon capturing a slow neutron the nucleus divides into two parts as described above. Assume in this case that the two fragments have the charges +50 and +42. (Sn and Mo) The heaviest stable isotopes of these two elements are Sn^{124} and Mo^{100} which have a total mass of 124 instead of the 236 of the splitting U nucleus. There is an excess of 12 neutrons to be divided between the two resulting nuclei. The immediate results of fission are ${}_{50}Sn^{127}$ and ${}_{42}Mo^{104}$. Notice that in this case only seven of the excess neutrons are retained by the two fragments. The remaining five are ejected with the two nuclei as free neutrons. Since both nuclei are unstable due to an excess of neutrons, they proceed to find stable nuclei of masses 127 and 104, respectively. Sn undergoes three beta-disintegrations to become stable ${}_{53}I^{127}$ while Mo carries out a similar series of two beta emissions to become stable ${}_{44}Ru^{104}$. The disintegration series is as follows.

$$ {}_{50}\overset{127}{Sn} \rightarrow {}_{51}\overset{127}{Sb} \rightarrow {}_{52}\overset{127}{Te} \rightarrow {}_{53}\overset{127}{I} $$

$$ {}_{42}\overset{104}{Mo} \rightarrow {}_{43}\overset{104}{Ma} \rightarrow {}_{44}\overset{104}{Ru} $$

The fission products are not limited to those given above. The uranium nucleus may break up into a large number of different pairs. Usually the fission is asymetrical, one fragment having an atomic number between 35 and 46 and the other between 47 and 57. It has been calculated that the most probable fission products would have atomic numbers in the neighborhood of 35 and 55. Until recently, fission products with atomic numbers 44 to 50 were not found. However, the work of several Japanese physicists has definitely established their existence with the exception of Sn(50). With this exception, then, fission products have atomic numbers 35 to 57 inclusive. As a result of the reaction there is a release of some 160 million electron volts (Mev) of energy. Neutrons, deutrons, gamma-rays, protons, alpha-particles are now known to be effective in splitting the heavy elements (i. e., thorium and uranium, since these are the only heavy elements that have displayed this phenomenon). The cross section or probability that fission will take place depends on the nature of the bombarding particle and its energy. Theoretically, the probability should increase with the energy of the impinging particle. This is shown to be true in the case of both the heavy elements with one important exception. In the case of uranium, fission is more probable with thermal neutrons (neutrons with the velocity of molecules in a gas) than with those over 10 Mev. of energy. For theoretical reasons Bohr assigns this phenomenon to one of the lighter of the uranium isotopes, U^{235}. The second fission process described above is an example of this type.

As we have said above, the reaction is accompanied with a release of a large amount of energy, about 160 Mev. Furthermore, when the nucleus breaks up into two parts several free neutrons are released with the fragments. Finally uranium fissures when bombarded with thermal neutrons. These facts give us our promise of unlimited atomic power. Once the first reaction is started, the free neutrons which result act as bombarding particles and set off another reaction in nearby atoms. These, in turn, fissure, release more neutrons and so a chain reaction is set up and the uranium is "burned" to furnish tremendous energy. This ideal situation is presented as it might be in the Sunday supplement of your newspaper. Actually the situation is not so ideal as it seems and the day of free atomic power is still far off. The energy of the neutrons released in fission is not well known as yet. There are indications that lower energy neutrons are more numerous than fast neutrons and that the average energy does not exceed one Mev. The number of neutrons produced by fission ranges from 1.5 to 3.5 neutrons per fission. This would seem to be sufficient to produce a chain reaction. However, the probability of scattering is more than 100 times greater than the probability of fission for one-Mev neutrons. Scattering reduces the energy of the neutron and with this the probability of a fast neutron fission. It seems very unlikely that fast neutrons can produce a sufficient number of fissions to maintain a regenerative action.

What about fission by thermal neutrons? In uranium, fission by slow neutrons is 40 times more probable than by the fastest neutrons (greater than 10 Mev). The difficulty here is slowing the one-Mev neutron down to thermal energies of about 1/40 of an electron volt. Collision with the surrounding uranium nuclei could not be very effective because they are so heavy that they absorb little energy by collision. Furthermore there is a resonance band at 25 ev where neutrons of that energy are absorbed by the U^{238} nucleus. To avoid this, it has been suggested that the uranium be diluted with some material containing hydrogen such as water. Collision of a neutron with the hydrogen nucleus (which is, of course, a proton with the same mass as the neutron) results in a large loss of energy and thus it would be possible for the neutron to jump over the 25 ev resonance band and thus escape capture. Of course, this would entail the loss of more neutrons by absorption in the added material.

Besides the difficulty of slowing down the free neutron to thermal energies, another factor is of importance. The energy involved per gram of uranium "burned" depends on the isotope responsible. The two principle isotopes of uranium have masses 238 and 235 and U^{238} is 139 times more abundant than U^{235}. Fission by fast neutrons and the capture of neutrons in the 25 ev band is attributed to the U^{238} nucleus, while fission by thermal neutrons is assigned to the much less abundant isotope U^{235}. For this reason, at the present time, uranium as a source of power, in terms of energy per dollar, is cheaper than coal by a factor of only 8.5. If uranium were to replace the 500,000,000

tons of coal used annually in this country the amount of uranium consumed would increase 15,000 per cent. This great demand, along with the necessary refinement of the ore, would greatly lessen the above factor especially since the limited reserves of high grade ore would soon be exhausted. From an economic viewpoint uranium power is not a good investment. Undoubtedly, special uses could be found for such a concentrated fuel but the day of free atomic power is not yet in sight.

At the beginning of this paper the several pretenders to the title of transuranic elements were comfortably disposed of and relegated to less exalted positions in the periodic table by the discovery of fission. However, our complacency in the nuclear situation is short lived. During the past year other claimants have appeared whose credentials, as far as they go, appear to be above suspicion. The resonance capture of a neutron at the 25 ev band referred to above results in a uranium nucleus of atomic weight 239. This nucleus, U^{239}, is beta-active with a half life of 23 minutes after which it becomes an element with an activity of 2.3 day half-life and, presumably, with atomic number 93. Uncertainty still exists in its identification. If it occupies a regular position in the periodic table beside uranium, it should be similar to Re^{75}. Since there seems to be no similarity, it has been suggested that it may be the second of a new group of rare earths of which uranium is the first. More recently the work of several Japanese physicists, later corroborated in very definite fashion by American physicists, brings to light a new pretender to the throne. Uranium was bombarded with neutrons for several days and from the activated material a uranium fraction was separated which showed a beta-activity of period about 7 days. Both groups of physicists came to the conclusion that it was U^{237} which, after decay, should become transuranic element 93, with properties similar to rhenium. An attempted chemical separation of this element gave a residue which showed no definite activity. It seems probable, therefore, that the period of this elusive substance is so long that its radiations are not intense enough to be detected by the methods yet available.

This paper ends where it began. The search for transuranic elements still goes on and the discovery of fission becomes merely a temporary digression. The story is far from ended; rather, the plot becomes deeper.

The writer wishes to make acknowledgement to the authors of the following publications for all the data presented in the above paper and to suggest the careful reading of these articles for a more complete and satisfying knowledge of the subject.

REFERENCES:

Mechanism of Nuclear Fission, Bohr and Wheeler, Phys. Rev. 56, 426 (1939).
Uranium and Atomic Power, Roberts and Kuper, J. App. Phys. 10, 612 (1939).
Missing Heavy Nuclei, L. A. Turner, Phys. Rev. 57, 950 (1940).
Nuclear Fission, L. A. Turner, Rev. Mod. Phys. 12, 1 (1940).
Physics in 1940, T. H. Osgood, J. App. Phys. 12, 84 (1941).
Introduction to the Theory of Nuclear Reactions, P. Morrison, Am. J. Phys. 9, 135 (1941).
Physics in 1941, T. H. Osgood, J. App. Phys. 13, 6 (1942).

CORRESPONDENCE OF GALILEO WITH PICCHENA AND BELISARIO VINTA CONCERNING THE GREAT LOADSTONE

The following letter and extracts were transcribed by Fr. Edward C. Phillips from: Le Opere di Galileo Galilei—Prima Edizione, Firenze Societa Eidtrice Fiorentina—Direttore della Edizione, Eugenio Alberi. (Vol.) Tomo VI 1847 (Tomo I del Commercio Epistolare) p. 41-43.

The first letter was freely translated into English by Mr. Joseph F. Costanzo, and the other extracts by Fr. Phillips.

Letter of Galileo to Curzio Picchena, Secretary of the Grandduke of Tuscany, Ferdinand I.

From Padua, 16 November, 1607

Two weeks ago I wrote to your Illustrious Grace about the piece of loadstone earnestly sought by Your Serene Highness; for at first I had a specimen,—such as it was, weighing one half pound, very strong in power of attraction, but of unsightly shape; and this was available at the behest of Your most Serene Highness,—Master of this and all else.

Shortly afterwards I told you of another specimen that was found in the possession of a gentleman, my friend (The Senator Giovanni Francesco Sagredo) a person of great generosity; this being a large piece which weighs five pounds and is nicely shaped. I said also that in order to contact that gentleman in Cadore I would write to him in order to ascertain his intentions (regarding the magnet). I have written him and have received an answer that he will part with the magnet provided that a price that corresponds to its worth is paid. And since it is now possible to obtain it I ought to tell you of some of the peculiar properties that I have oberved repeatedly in this magnet, since I have handled it many times. First it is so strong that it sustains a piece of iron a finger long and as wide as a writing pen;—to which may be attached 6 and one half pounds of any matter. And I believe, if I recall correctly, that the 6 and one half pounds are taken according to the local measures which in fiorentino weights would be about ten pounds.

Attaching a small particle of iron, not longer than half a seed of grain, the magnet held on to it together with the equivalent weight of three very small coins placed after it. It has such great force that if we place the tip of a large scimitar as close to the magnet as the width of a silver coin, any strong person who holds the handle near his chest must needs pull vigorously to release the scimitar.

I then discovered another marvellous effect which I have never seen in any other loadstone; namely that the *same side will both repel and attract the same iron.* The magnet draws it when the metal is

placed four or five fingers away, but if the metal is moved to within a finger's distance or so, the stone repels it! So that if we place the metal upon a table and approach it closely with the stone the metal moves away, but upon drawing the loadstone back about four fingers the iron begins to move towards it and follows it as the stone is further withdrawn. But no sooner do we approach it within a finger's distance, as I have already said,—face on with the loadstone, the iron is repelled and "retreats". The other effects of the loadstone follow as a consequence of its great force.

This gentleman has written me that a German jeweler has offered him 200 gold scudi, desiring to obtain it for his Emperor, but he did not want to part with it for that amount estimating it to be of greater value. I have not disclosed to this gentleman the identity of the person seeking it, nor will I do so unless you tell me to act otherwise. Since the aforesaid gentleman is located a great distance from here I did not receive an answer from him until to-day. From his answer I am able to infer for what amount he will part with the loadstone, (from whose effects he derives such great pleasure) as he values it more than 400 scudi. Many times I have heard him say that he would not give it up for all the gold which, attached to a piece of iron, would be moved by the magnet,—which amount would be more than 800 scudi. However, he has not written anything about this.

I await further instructions from your Lordship regarding the amount I should offer so that I may not be found wanting in obedience to the wishes of our Lord the Prince, before whom I humbly bend my knee, and also kiss the hand of your Lordship with every mark of affection.

Continuation of correspondence of Galileo with Picchena and Belisario Vinta (First Secretary of State of Ferdinand I and Cosimo II, Granddukes of Tuscany concerning the great Loadstone Ferdinand desired to obtain).

4 Jan., 1608. Galileo acknowledges receipt of Picchena's instructions which state that the Duke would like to buy the Magnet, but not at the price the owner demands. Galileo informs Vinta that he has written to Senator Sagredo asking him to lower the price. The Senator responded that he would not insist on the suggested price and leaves the matter to Galileo's prudence.

8 Feb., 1608. To Vinta. Galileo states that Sagredo has sent him the Magnet and will stand by whatever arrangement for its sale Galileo will make, and in order to please Galileo and his friend (Sagredo did not know who it was that desired to secure possession of the magnet) he would be willing to take 200 scudi in gold or even in silver. Galileo understands that the Grandduke consents to buy the magnet only under condition that it will support at least its own weight of iron.

Galileo is glad to have received the magnet into his keeping so as to be able to experiment with, to make sure of its strength, etc. The magnet weighs 53 ounces (oncie a questo peso)—about 5 pounds on the Florentine standard. The exact weight is however not important, for it upholds more than 5½ pounds, and Galileo thinks he can find by experimentations the way to make it sustain a greater weight: one has to find the two poles: then the amount the magnet will hold up depends not only on the magnet but also on the shape and the character of the iron armature used: already he has been able by trying various piece of iron of various shapes at various points of the magnet to make it sustain a weight about one pound greater than the owner had ever been able to pick up with it—a slight displacement of the position of the armature makes a considerable difference in the weight it will hold. He is having a few armatures made of the finest steel (acciaio finissimo) with which he hopes to make the magnet carry even a much greater weight.

He has also verified the other marvelous effects produced by the magnet especially its property of repelling and attracting with the same face or pole one and the same piece of iron (in this letter he speaks of having had two small cylinders of steel made for the purpose)—according to the distance of the magnet: this property seems to be peculiar to this individual stone as he has never been able to produce the same effect with any other of the many magnets with which he has experimented.

As to the price—he requests that in place of the two hundred gold scudi the Duke give 100 "doble" (doubloons).

Vinta informed Galileo, 22 March, 1608, that the Grandduke accepts the conditions, and will give the 100 doubloons. Galileo is to pack the magnet carefully and send it to the Duke.

4 April, 1608. Galileo to Vinta. Is most grateful to the Duke for consenting to give the doubloons as of more value than the scudi; his (Galileo's) sincerity has thus been proved to his friend Sagredo who had suspicions that Galileo was not making sufficient efforts to obtain for him a reasonable price. He will send the magnet as soon as he has received definite instructions as to whom it should be delivered. He will see that the magnet is packed properly supplied with its armatures and accessories. He requests that the doubloons be sent to Venice and he himself will go there with the magnet as soon as he has been informed of the consignment of the money. Having received the money he will pay it into the hands of the present owner and then hand over the magnet to whomsoever the Duke may have appointed as his agent to receive it.

3 May, 1608. to Vinta. Galileo informs Vinta that he has forwarded the magnet—he would have liked to keep it longer to continue his experimentations. He has succeeded however in making it sustain

considerably more than twice its weight: it weighs six pounds, holds up more than twelve. He thinks with better armatures, specially made, it would hold still more. The two armatures which accompany the magnet have been made in the form of anchors: the arms of the anchors form convenient hooks on which to add extra weights until the total strength of the magnet has been reached, as the anchors (armatures themselves) have been made (definitely) lighter than the weight the magnet can carry. He thinks that if he would have an opportunity for further experimentation he could arrive at finding means of making the magnet hold up four times its own weight "which in a stone of such size is very wonderful." He adds that if the magnet were cut up into smaller pieces the collection of magnets thus formed could be made to sustain thirty or even forty pounds of iron.—Another wonderful thing is that the magnet does not grow tired in sustaining its weight, but grows stronger in doing so.

. . . . The letter contains other interesting points.

An interesting item in his letter of Feb. 8, 1608. He says the mails were delayed by the great amount of ice and snow which have blocked the road between Venice and Padua; he adds: "e di presente ancora aviamo qui in Padova la neve alta per le strade quatro e cinque braccia, cosa horribile, che supera le memorie degli uomini et delle carte." Vinta's letter of January 13 (from Florence?) did not reach Padua until Feb. 3rd.

This great loadstone was lost. Even in 1698 Leibniz deplores the fact that this marvelous stone could not be found; all trace of it had disappeared. This he considered a great loss to science which could learn much from experimentation with magnets in general and with this magnet in particular. Alberi, the Editor of The "Opere", states that at present, i.e. in 1847, nothing whatever is known of the stone, no trace of it exists.

SEISMOLOGY AND GEOLOGY

A PREGLACIAL CHANNEL

Clarence N. Blais, S.J.

Since the beginning of the last century geologists in and around Boston have given much of their attention to the geology of the city and its immediate vicinity. It has been said that probably no other large city has such varied geology so easily available. Quite naturally many a budding scientist found ready material for his graduate work and in later days found it very profitable to continue his work in this same area. Other geologists, many of them being of high repute in geological circles, were interested in various problems and found it worth their while to devote time and effort to the study of local formations. Consequently, hundreds of books, bulletins, and pamphlets on the Boston area have been printed and are still being published[2]; and the surface geology of this whole section has been well mapped.[3]

Among the many problems that still hold the interest of geologists, there is one which, at present, receives no little attention, namely, the courses of Boston's pre-glacial rivers.[4] Until very recently it was generally accepted that the pre-glacial Merrimac River did not turn eastward at Lowell, as the present river does, but flowed down through the region now covered by the Mystic Lakes, continued southward, and finally turned eastward through the center of what is now Boston, and into the sea.[1] As a result of recent seismic surveys by F. W. Lee and his associates in the Lowell Quadrangle, this supposition is now open to dispute.[4] The present Mystic River flows directly southeastward from the Mystic Lakes into the harbor. A problem has arisen and can be stated: Was there also a pre-glacial Mystic River draining the area between the present Mystic Lakes and the sea? If so, then what was its course? How closely did it follow the present river?

Several geologists have been gathering data on this problem over a period of years. Their actual figures consist chiefly of the evidence of drillings, either for wells or other purposes. According to the data collected up to the present, there seem to be two channels, one coming directly southward from Malden and the other paralleling the course of the present river.[5] Both channels meet at a point in the Mystic a little to the North of the Alford Street Bridge, which joins Charlestown and Everett. From here the channel follows a course in the general direction of the present river. That portion of the substratum in which the original channel is situated is a synclinal area of Cambridge argillite, i.e., a down-folded belt of hardened clay, which is known to deepen to the east.[2]

A little more than a year ago, the Boston Edison Company had decided to erect a large power station on the Everett side of the Mystic River near Sullivan Square, Charlestown, Mass. The plans for the erection of a large power station over loose material require accurate figures on the depths to bed rock, since any appreciable settling of the completed structure could entail very costly inconveniences. Hence a seismic survey was suggested in order to supplement the drilling data. The Weston College seismic unit under the direction of Father Linehan, assisted by Dr. Leet of Harvard, conducted this survey.

The material covering bed rock along this section of the Mystic consists of recent deposits of silts, sands, peat, clays, and glacial gravels. This whole unconsolidated surface stratum averages about 130 feet in depth. Since this is relatively shallow, the seismic 'refraction method' was used in the survey. This method consists essentially in measuring the velocities of waves in the upper layer and in the underlying rock and comparing them. A charge of dynamite is exploded and the time required for the vibrations to travel to a number of seismic stations is accurately recorded. Some of the waves travel downward and in the direction of the line of seismic stations. Since the velocity of the waves increases with depth, they are refracted and the line of propagation describes a slight arc dipping into the ground then coming up to strike the seismometers. Other waves travel down to bed rock, trace a similar curve in this layer, then emerge into the upper substance by refraction and travel to the seismometers. If the velocity of waves in rock is greater than in the overburden, beyond a certain point in the line of instruments they will arrive before the more direct waves, even though their paths are longer. These travel times are the data from which the depth to bed rock is computed.

The time of arrival of wave fronts depends chiefly on two factors; the paths of the wave fronts and the velocities of vibration in the different materials. A careful selection of the shot point and the positions of seismic stations along a definite line makes it possible to calculate the distance from the top of one stratum to the next. In this survey six geophones were placed in each line at intervals of 100 feet, and the shot points 100 feet from the first station in each line. A series of such lines furnished data for a 'seismic profile' of the area.

In some locations a preliminary calculation of depths to bed rock showed fairly wide discrepancies with the drill data. The drillers went to work again on one of the disputed sections and their findings merely checked their original figures. But an analysis of the rock at the bottom of the hole showed that the substance was quartzite, a rock found about five miles distant in Medford, and not the slate which forms the bed rock of this section of Boston. Actually they had merely struck a glacial deposit. Further penetration with a diamond drill confirmed this conclusion and the depth to bed rock agreed with the seismic figures. Later when the contractor drove large steel piles

down to rock, according to specifications of the seismic survey, they checked accurately with the calculated depths.

The report of this March, 1941, survey contains a contour map plotted from the seismic data.[6] It reveals that the bed rock in this section has an average elevation of approximately −120 feet. (Figures are referred to the Boston Base Line.) It also shows a well-defined pre-glacial channel running along a north-south line. Its average width is approximately 50 feet along the crests of its banks and the lowest point descends to −161 feet, or about 40 feet below the average elevation in the vicinity. This is the channel that has lately played a prominent part in geological speculations.

Among the many geologists who have been working on local formations Irving B. Crosby is quite prominent, particularly for his zeal to further his father's momentous work on Boston Geology. In his opinion this pre-glacial channel gives added confirmation to the belief that the course of the original Mystic had been accurately located in this section. The channel, he said, formed a tributary which emptied into the larger river.

Later in the year, the Edison Company decided to build a cable tunnel under the present river. The engineers of the project had to know the depths of the rock under the glacial deposits. With definite knowledge of the geological formation, they could choose that site which would entail a minimum of boring through rock, or perhaps would avoid it altogether.

This survey proved to be a very interesting project for the Weston Seismic Unit. Up to this time all surveys had been made on more or less firm ground, but this project required lines of seismic stations set out under water. Many changes had to be made in the equipment. Specially designed submarine geophones replaced the ordinary units. A floating unit, anchored in the river gathered all wires from the various stations and formed a stationary base in the water and prevented connections from becoming wet. Several thousand feet of multiple-channel wire connected this base to amplifiers and recording camera in the truck on shore.

A number of difficulties arising from wind, tide, and even fog, hindered the work to such an extent that four or five times the normal period was required to collect data. For instance, when one of the seismologists attempted to plant a geophone on the river bottom with the aid of a long pole, he had to gauge the drift of his boat and then, at the right instant, plunge his pole into the mud. He often had to make several attempts before he obtained a satisfactory emplacement. After a day or two of such maneuvering this method was abandoned. Stakes, some of them 30 feet in length, depending on the water depth, were driven into the mud. These stakes were chained off to 100 ft. distances marking the stations where the seismometers would be located.

These stakes were then located by surveyors on shore and placed in a map. Special reels for the connecting cables were slung on a cradle in the boat and the wire fed out from station to station. In order to insure a sufficiency of energy driven into the ground, the explosive must be well covered. This is achieved by having a sufficiently long column of water above the charge. It was necessary therefore to shoot the charges at the proper tide, and this limited the daily work to one profile and its reversal. Other difficulties arose from connections of wires to seismometers. Water seeping into connections in some cases caused a closing of the seismometer circuit and we would pick up the 60-cycle wave from a transformer station on shore. This required less amplification in order to lessen its effect and more explosives per shot. The same defect would likewise cause crossfeed from one pick-up into the channel of another in the same cable. In spite of these difficulties a sufficient number of clear accurate soundings were finally recorded.

Now we have actual figures taken directly above what is supposed to be the pre-glacial Mystic River.[7] Plotted as a contour map they are somewhat startling when compared with the adjacent channel. The topography under the river is fairly simple. The variations of bed rock elevation are gradual and there is no evidence of narrow gorges or narrow rises. The surface of rock dips slowly to the northeast at an average gradient of four degrees. At widely separated points depths range from −75 feet to −145 feet, which is still 15 feet higher than the adjacent channel. Unfortunately the survey did not extend far enough to the south to gather sufficient data across the whole mouth of the channel. However, the map does clearly delineate the western half. Any water collected in this area could easily flow through the channel but it had to flow *away* from this section and not *into* it. According to the evidence of this contour map it is highly improbable that any large river had its bed in this section. If we accept the conclusions of geologists that a pre-glacial river once existed somewhere in the vicinity, then it must be at the other end of our channel, i.e., somewhere to the north, or northeast, of the present Mystic River.

1.—Crosby, Irving B. "Boston Through the Ages." Marshall Jones Co. Boston 1928.

2.—LaForge, Laurence. "Geology of the Boston Area Massachusetts." Bull. 839 U. S. Geol. Survey.

3.—Crosby, W. O. "Contributions to the Geology of Eastern Masachusetts." Boston Soc. Nat. Hist. 1880.

4.—Lee, F. W., Farnham, F. C. Raspet, A., Currier, L. W. "Seismic Method for Determining Depths in Bed Rock as applied in Lowell Quadrangle. U. S. Geol. Survey, Geologic Project Special Paper 3.

5.—Commonwealth of Massachusetts, Special Report (House 262) of the Met. Dist. Water Supply Comm. Dec. 1, 1937.

6.—Linehan, D., S. J., Leet, L. D. "Seismic Survey Mystic Station Site" Boston Edison Co. March 1941 (unpublished).

7.—Linehan, D., S. J., Leet, L. D. "Seismic Survey Mystic Cable Crossing" Boston EdiSon Co. Jan. 1942 (unpublished).

GREAT LAKES TIDES IN THE JESUIT RELATIONS[1]

Rev. A. R. Schmitt, S.J.

Our early French missionaries in Canada, just as elsewhere in the world, were interested not merely in the supernatural but in all natural phenomena as well. The *Jesuit Relations* gave Europe its first information about much of the geography, climate and the fauna and flora of New France. What I wish to tell you particularly about here is the interest manifested by such well-known Jesuit missionaries as Fathers Ragenau, Bressani, Dablon, Andre, Allouez and Marquette in the ebb and flow of tides on our Great Lakes. Many observations of these tides, or what seemed to be such, are recorded by these men and most of them were made on Lake Michigan (Lake Illinois to them) at Missilimakinac, in Green Bay and the Fox River and even here at the present Chicago shore just off the Loop.

In the *Relation* of 1670-71 "Of the Mission of St. Ignace at Missilimakinac", Fr. Claude Dablon writes:

"The second inconvenience (the first was strong winds) arises from the tides, concerning which no fixed rules can be given. For whether they are caused by the winds, which blowing from one direction or another, drive the water before them and make it flow in a sort of flow and ebb; or whether they are true tides, and hence some other cause explains the rise and fall of the water, we have at times noted such irregularity in this action, and again such precision, that we cannot yet pronounce upon the principle of these movements, so regular and again so irregular. We have indeed noted that at full and at new Moon the tides change each day, — today high, tomorrow low, — for eight or ten days; while at other times hardly any change is perceptible, the water, maintaining nearly an average altitude, neither high nor low, unless the winds cause some variation.

"But in this sort of tide three things are somewhat surprising. The first is, that it almost always flows in one direction here,—namely toward the Lake of the Illinois, — and meanwhile it ceases not to rise and fall as usual. The second is, that it runs almost always against the wind, sometimes with as much strength as the tides before Quebec; and we have seen cakes of ice moving against the wind as rapidly as ships under sail. The third is, that amid these currents we have discovered a great discharge of water gushing up from the bottom of the Lake, and causing constant whirlpools in the strait between the Lake of the Hurons and that of the Illinois. We believe this to be an underground outlet from Lake Superior into the two latter lakes; and, indeed, we do not otherwise see any other answer to two queries, — namely, what becomes of all the water of Lake Superior, and whence

[1]Paper read at the National Convention of Jesuit Scientists held at Chicago, Illinois, Sept. 1940.

comes that in the two lakes of Hurons and of the Illinois? For, as to Lake Superior, it has but one visible outlet, which is the river of the Sault; and yet it is certain that it receives into its bosom more than forty-five rivers, of which fully twelve are wider and of greater volume than that of the Sault. Whither, then, does all that water go, unless it finds an issue under ground and so passes through? Moreover, we see only a few rivers entering the Lakes of the Hurons and of the Illinois, which, however, are of enormous size, and probably receive the greater part of their water by subterranean inlets, such as that one may be of which we are speaking."

Again in the *Relation* of the following year, 1671-1672, Fr. Andre writes from the mission at Green Bay:

"Following is what the Father Andre writes on this subject: 'Hitherto I have not shared the opinion of those that believe that Lake Huron is subject to an ebb and flow, in common with the sea; because I had observed no fixed movement of the sort during the time of my sojourn on the shores of that lake. But, after passing the so-called "wild-oats river", I began to suspect that there might really be a tide in the Bay des Puans (i.e. Green Bay). We had left our canoe in the water, in very calm weather; and the next morning we were greatly surprised to find it high and dry. I was more astonished than the rest, because I bore in mind that for a long time the lake had been perfectly calm. Thereupon, I determind to study this tide, and at the outset reflected that the contrary, but very moderate, wind did not prevent the flow or ebb, as the case might be. I also became aware that, in the river emptying into the bay at its head, the tide rises and falls twice in a little more than 24 hours, — rising usually a foot; while the highest tide I have seen made the river rise three feet, but it was aided by a violent Northeast wind. Unless the Southwest wind is very strong it does not check the river's course; so that ordinarily the middle flows constantly downward to the lake, although at each end the water rises with the fixed periods of the tide. As there are but two winds prevailing on that river and on the lake, one might easily ascribe to them these tides, were it not that the latter follow the Moon's course, a fact which cannot be doubted; for I have ascertained beyond a question that at full Moon the tides are at their highest, then they fall, and they continue to diminish as the Moon wanes. It is not surprising that this flow and ebb is more appreciable at the head of the bay than in Lake Huron, or in that of the Illinois; for were the tide to rise even but an inch in these lakes, it would necessarily be very noticeable in the bay, which is about 15 or 20 leagues long by five or six, or more, wide at its mouth, and narrows constantly. Consequently the water, being contracted within a small space at the head of the bay, must of necessity rise much higher there than in the lake, where it is less confined.' "

(Thwaites: *Jesuit Relations*, Vol. 55, pp. 163-165).
(Thwaites: *Jesuit Relations*; Vol. 56, pp. 137-139).

Fr. Andre adds more observations and more speculation in a letter of the next year, 1673:

"The small quantity of paper that I have left reminds me of the promise that I made to Your Reverence last year, at the end of one of my letters, to tell you what might seem to me (I must not forget to tell what seems to me) to be worthy of note in connection with the ebb and flow of our river. It is quite certain that it has its tides like those of the seas, — or, more properly speaking, of the rivers that fall into them. The unusual severity of the winter this year caused me to make an observation that hitherto could not be made. During the month of March I remarked that the highest winter tide is lower than the lowest of all the tides of the other seasons, when neither the bay nor the river is frozen. It was necessary to advance a considerable distance on the river to find water under the ice, which was a foot and a half thick; and the surface of the ice was not higher than the low tides of summer, or the average of both the highest and lowest tides.

"I also observed that the volume of water increased in our river during that month, in proportion as the ice in the bay of Saint Xavier diminished and broke up. This cannot be attributed to the greater abundance of water flowing from above, because the tide extended only as far as the foot of the rapid,—which is easily seen at present, but not in summer, when one does not observe (perceive) that there is a rapid, because the lowest tide is generally higher than it. These two observations have troubled me, for I formerly believed that the winds were not the cause of the tide. Were I permitted to Philosophize, I would argue against those who attribute the formal cause thereof to rarefaction, special or general. For if the water rarefies and then condenses, all that great mass of water of the Lake of the Illinois rises in its vast basin when it rarefies, and falls when it condenses. And as water always rises as much as it falls, it would follow that, however thick the ice of the bay and of the river might be, they would offer no more resistance than a pipe, — which, however thick it may be, never prevents the water from rising as much as it has fallen, for it does not press against it. And, although it may be said that the ice presses on the water, still it cannot be said that it prevents the water from rising; for, while pressing on the water, it floats on it; and the ice should be higher than the highest tides of summer and of autumn, or of spring,— or, at least, than the mean tides, which is not the case. Opposite the folle avoine, the ice was three feet thick,—that is. where the bay begins, But twelve leagues from there, as one approaches the bottom of it and our river, the ice was about a foot and a half thick. Your Reverence knows better than I the length and width of the bay, so I shall not speak to you of them. If the cause of the ebb and flow be attributed to the winds, there will not be much difficulty in explaining how it happens that the lowest tides at the periods when there is no ice are higher than the highest tides of winter. For it will be said that the water, impelled by a violent motion, loses its force in proportion as it strikes against ice beneath which it flows, and consequently less water

runs into the bay. I conclude by informing Your Reverence that the ice in the bay has commenced to break up toward the bottom, and not on the side of the entrance toward the open water of Lake Illinois, where the ice was three feet thick."

In estimating the value of Father Andre's speculations it must be remembered that he recorded them about 15 years before the publication of Isaac Newton's "Principia" which is the starting point of modern theory of the tides as well as of so much else in the science of Physics.

The letters which I have quoted were read in France by Claude Bernou, an unpublicized gentleman who was greatly interested in winds, tides and currents in all parts of the world. His information was gathered mostly from relations of voyages and of missionary labors and travels in foreign lands. In the Library of Congress there is a large manuscript volume of his in which Fr. Jean Delanglez, Research Professor in the Institute of Jesuit History, has found that Claude Bernou gets into our present picture. In 1674 or 1675 he sent a questionaire about tides and other phenomena to a certain Barrois, an agent of the company which then ruled Canada. Bernou added this comment:

"If at the end of the Bay des Puans (Green Bay) and towards the river of Wild Oats there is usually an ebb and flow, at least in times of calm and sometimes in spite of a contrary wind such as the relations of the Reverend Jesuit Fathers of 1671 and 1672 state there is, this fact is alone capable of refuting the opinion of Descartes. Since many people refuse to accept one single observation (as conclusive) I would wish to have this confirmed either by the Reverend Jesuit Fathers or by some other person interested in the matter."

Fr. Delanglez is still trying to find out what the opinion of Descartes about tides or about something closely related to them was which Bernou seemed so anxious to refute. I was very sanguine in my own hopes of an early, if not immediate, solution until I came face to face in our library with six large volumes of Descartes bound in beautiful royal blue. As far as I am concerned all six volumes still guard their secret, but Fr. Delanglez is much more persistent. Some day the secret will out.

For the purpose of the present account, however, it is enough to say that Bernou's questionaire was handed on by Barrois, to whom it was addressed, to St. Martin who was teaching mathematics in the Jesuit college at Quebec. It is probable that St. Martin showed Bernou's questionairre to Fr. Dablon, who was the Jesuit superior in Canada at the time. Perhaps Fr. Dablon was approached by Dalera, a second and later agent of Bernou on the same matter. In any event we find these later comments on the Lake Michigan tides in the *Jesuit Relations*.

The first appears in the relation of Fr. Marquette's first voyage, which Fr. Delanglez tells me, was rewritten by Fr. Dablon.

"The bay (Bay des Puans, now Green Bay) is about thirty leagues in depth and eight in width at its mouth; it narrows gradually to the

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(Thwaites: *Jesuit Relations;* Vol. 57, pp, 301-305).

bottom, where it is easy to observe a tide which has its regular ebb and flow, almost like that of the sea. This is not the place to inquire whether these are real tides; whether they are due to the wind, or to some other cause; whether there are winds, the precursors of the Moon and attached to her suite, which consequently agitate the lake and give it an apparent ebb and flow whenever the Moon ascends above the horizon. What I can positively state is, that, when the water is very calm, it is easy to observe it rising and falling according to the course of the Moon; although I do not deny that this movement may be caused by very remote winds, which, pressing on the middle of the lake, cause the edges to rise and fall in the manner which is visible to our eyes."

This last remark of Fr. Dablon, which he offers as a possible explanation of the observed variation of lake levels, comes very close to the explanation now offered for the seiches, or sudden dips and surges recorded on lake level gauges at Chicago and other lake ports; it only needs to be stated in terms of our modern theory of gas pressures.

The last brief quotation which I present on this subject of lake tides from the *Jesuit Relations* is from Fr. Marquette's own autograph account of his second voyage, in his unfinished journal. The place which Fr. Marquette refers to is his cabin near the mouth of the Chicago River.

"We have had opportunity to observe the tides coming in from the lake, which rise and fall several times a day; and although there seems to be no shelter* in the lake, we have seen the ice going against the wind. These tides made the water good or bad, because that which flows from above comes from prairies and small streams."

Our first Jesuit missionaries in these parts were not delinquent in employing their powers of observation or, what is of equal importance, in recording what they observed. They were merely handicapped by the fact that the development of the science of Physics lagged behind.

Henry Norris Russell has the following brief comment on tides on large lakes, and on our Great Lakes in particular:

"In even the largest lakes the tides are very small,—much less than the variations in level due to wind and weather,—and they can only be detected from the average of long series of observations. At Chicago the tide in Lake Michigan has a range of about 1¾ inches."

I am informed by the engineers of the Sanitary District of Chicago, who have for many years operated continuously recording gauges of lake levels at the port of Chicago, that it is extremely difficult if not impossible to identify on their records any rising or falling of the water as being due to true tides.

I hope that it has been worth while to have someone tell this bit of early Jesuit endeavor in science on the occasion of the Quadricentennial of the Society of Jesus.

(Thwaites, Vol. 59, pp. 99—*Relation* of 1673-77—Marquette's 1st Voyage).
(Vol. 59; pp. 179—*Unfinished Journal of Marquette*. March, 1675).
* By "shelter" Fr. Marquette may mean "a place (for the ice) to run to."

BRIEF OBITUARIES

OBITUARY

Fr. Adolf Mueller, S.J.

(1853-1939)

After a busy life the tireless wanderer has gone to his eternal rest. Father Adolf Mueller was educated in the German College, Rome, 1872-1879. On the 10th of October, 1879, he entered the Society of Jesus at Exaten. Later, he made special studies in astronomy at Kalocza (Hungary), Berlin and Stonyhurst (England). His tertianship was made at Portico. From 1885-1894 he was diocesan seminary director in Bombay. Later he became minister of the house and professor at Puna; he was professor at the Gregorian and director of the observatory on Janiculus Hill. In the eternal city and during his many vacations in Germany, he was constantly engaged in apostolic work as well. He also became rector of the German College.

His publications include: "Nikolaus Kopernicus", "Johannes Keppler", "Elementi di Astronomia" (2 vols), "Galileo Galillei und das Kopernische Weltsystem" and "Der Galileo Prozess". Besides, he contributed a great deal to the professional literature.

Since 1915 his work has taken him to Feldkirch, Elberfeld, Trier and Luxemburg. In Trier and Luxemburg he was the superior of the house. On returning to Trier he tallied 99,363 confessions during his five years stay. He then went to Dortmund, and then to Godesberg, first at the Gymnasium and then at Saint Vincent's House.

The decline that goes with age was beginning to show, and this spring he left Saint Vincent's for Essen. Here he still managed to direct a student through a five-day retreat, and he could keep quite occupied in his room. Out walking one day he was run down by a bicyclist. An injury on the hip joint that resulted, deprived him the use of his left leg. After a few days, however, he appeared on crutches. Still when he would fall from these and get bruised in the head, one would find him again on the corridor outside his sickroom, even shortly before his death, making the stations of the cross on crutches. When Father Lindworsky was anointed on September 7th, 1939, he also received the sacrament with great devotion. On the next day he celebrated the Holy Sacrifice,—for he had permission to celebrate while seated. In the night before September 11th, 1939, he passed away peacefully. R.I.P.

translated by Rev. B. A. Fiekers, S.J.
AUS DER PROVINZ,
Series 7, No. 44, p. 189, (Nov. '39).

O B I T U A R Y

Fr. John B. Lindworsky, S.J.

1875-1939

On the fourteenth of July Father Lindworsky was brought from Kochel to our house in Essen. Those of his former students and friends who visited him here were astonished at the change that had come over him. Instead of the stately professor they once knew they found one paralyzed, blind and in great suffering from the shocks he had sustained. In the very best years of his activity, mental and bodily suffering had overtaken him.

One has only to recall his disappointment in the University of Cologne where he had looked forward to the chair of ordinary professor for experimental psychology, and then found himself forced to accept the ordinary professorship at the German University of Prague. After that he had just finished the winter term at Prague, the visiting lectureship in Rome and the many sessions of the psychological congress in Vienna that usually went far into the night, only to succumb to his first shock while at work in the Institute on the second day of the summer term. From this he was paralyzed on the left side. After some convalescence in Kochel, he undertook professional duties anew in Prague and in hard, steady work continued them for almost seven years.

But in the winter term 1938-1939 a second attack deprived him of his eyesight and forced him to abandon academic work. Thus one of our best men came to the Essen residence. But his enterprise could not be paralyzed. During the two months that were still his, he wrote his memoirs, "Religioese Lebenskunst". Hardly had he finished with this when a third attack overtook him to paralyze his tongue. He celebrated the Holy Sacrifice with great effort for the last time on the Feast of the Assumption. About three o'clock on the day that followed the Feast of the Nativity of our Lady, (September 9, 1939) he went to his eternal rest. R.I.P.

translated by Rev. B. A. Fiekers, S.J.

AUS DER PROVINZ,

Series 7, No. 44, pp. 188-9 (Nov. 1939).

NEWS ITEMS

BOSTON COLLEGE PHYSICS DEPT.

Fr. Tobin gave an address on Cosmic Rays to the Joint Session of the Eastern Association of Physics Teachers, New England Biological Association and New England Association of Chemistry Teachers. The meeting was held at Boston College on Saturday, December 6th.

Courses in Radio Communications, Radio Communication Measurements, Optical Instruments and Principles of Applied Physics will start this month in the Engineering, Science, Management Defense Training Courses.

In the college full time day courses now being taught are, Meteorology, Ballistics, Optical Instruments, Advanced Radio Communications and Radio Operators Procedure. The courses in Mechanical Drawing and Shop Practise as taught to the Freshman B.S. in Engineering were opened to other students who wanted Defense Courses.

CANISIUS COLLEGE—DEPT. OF CHEMISTRY

On Tuesday, December 9, 1941, the Chemistry Faculty of Canisius College was host to the Western New York Section of the American Chemical Society.

At a reception at 6 P.M. in the Chemistry Library Very Rev. Timothy J. Coughlin, President of the College, met Mr. Wilmer H. Koch, chairman of the Section, and the chairmen and members of the various Committees of the organization.

At the close of the reception the visitors were shown the classrooms and laboratories of the Horan-O'Donnell Science Hall by T. Joseph Brown, S.J., chairman of the Department of Chemistry.

Following this dinner was served in the cafeteria to seventy members of the Section and their guests, among whom were Father Coughlin, Father O'Sullivan, S.J., Dean of the College, and Father Schlaerth, S.J., Regent of the Graduate School.

The guest speaker was Rev. Francis W. Power, S.J., assistant professor of Analytical and Microchemistry at Fordham University, who spoke at the close of the dinner on "Methods and Applications of Microchemistry."

At a public session at 8:30 in the auditorium Dr. Cecil E. Boord lectured on the "Synthesis of Pure Hydrocarbons and the Relations of their Physical Constants to Molecular Structure." At the close of Dr. Boord's talk many members remained to hear President Roosevelt's radio address.

Members of the Section were unanimous in deciding to return to the College for future meetings and plans are being made to that effect.

A course in the elements of glass blowing will be started at the beginning of the second semester for the Junior and Senior students majoring in Chemistry.

To accommodate the students a fully-equipped glass blowing table has been constructed and placed in the rear of the organic laboratory.

Dr. Liberatore, professor of Physical Chemistry, will direct the course.

A report from twenty-two graduates of 1941 who majored in Chemistry shows six studying Chemistry in Graduate Schools, twelve in Chemical plants, one attending a Medical School, two in industry in non-Chemical work, and one in the U. S. Navy.

FORDHAM UNIVERSITY, BIOLOGICAL LABORATORY

Summer Session 1942: The registration in the biological section of the Summer Session was considerably increased last summer by offering some new courses and bringing in outstanding Catholic biologists as visiting professors. This summer in addition to the regular courses by our staff the following attractive courses will be offered:

Genetics given by Rev. Edward J. Wenstrup, O.S.B., Ph.D. (Pittsburg), Head of Department of Biology at St. Vincent College, Latrobe, Pa.

Animal Behavior given by Rev. Walter H. Belda, Ph.D. (Hopkins), Head of Biology Department, St. Francis Seminary, Wisconsin.

Comparative Embryology given by Sister Florence Marie S.C., Ph.D. (Columbia), Head of Biology Department, Seton Hill College, Greensburg, Pa.

Botany (*Phycology*) given by Dr. Harold C. Bold, Ph.D., (Columbia), Dept. of Botany, Barnard College.

FORDHAM UNIVERSITY, PHYSICS DEPARTMENT

New York, N. Y.

January 14, 1942.

The following papers were read at the American Physical Society meeting at Princeton:

"The Effect of Changes of Height of Air Mass on Mesotron Intensity"—Dr. Victor F. Hess.

"Cosmic-Ray Measurements between New York and Valparaiso" —Rev. Edward B. Berry, S.J.

On December 11, Father Lynch received from The New York Academy of Sciences the following letter:

"We take great pleasure in informing you that at the Annual Dinner held December 10th, 1941, The New York Academy of Sciences, of which you are an Active Member, unanimously elected you a Fellow of the Academy in recognition of your achievements in Science.

Election to Fellowship is a distinguished honor, conferred on a limited number of active Members, who, in the estimation of the Council, have done outstanding work toward the advancement of Science."

The following Defense Courses are now offered by the Physics Department of Fordham College:

Mathematics—Father Lynch.

Wednesday, 6-7:15 P.M. Saturday, 11-12:15 A.M.

This mathematics course is for those who have not taken mathematics since High School. It will necessarily be an intensive course and will cover the essentials of Algebra, Trigonometry, Analytical Geometry, Calculus and Differential Equations.

Text: Fleming—"Elementary Mathematics for Engineers."

Navigation—Naval and Aeronautical—Father Berry.

Wednesday, 7-8 P.M.

Saturday, 12-1 P.M.

Texts: Bowditch—"American Practical Navigation".
Holland—"Avigation".

Meteorology—Dr. Hess.

Monday, 5-6 P.M.

Friday, 5-6 P.M.

Text: Piston—"Meteorology".

Electricity—Dr. Lynch.

Tuesday, 4-5 P.M.

Saturday, 9-10 P.M.

Text: Timbie—"Elements of Electricity"—*3rd* Edition.

Combustion Engines—Mr. McNiff.

Tuesday, 5-6 P.M.

Thursday, 5-6 P.M.

This course will include steam, gasoline and Diesel engines.

Ballistics and Airplane Mechanics—Mr. Hurley.

Wednesday, 8-9 P.M.

Saturday, 10-11 A.M.

Regular sessions began Monday, January 5th.

GEORGETOWN UNIVERSITY—PHYSICS DEPT.
For 1942-1943

In order to carry on more efficiently the work of training men in PHYSICS, a field so important for National Defense, the Graduate School of Georgetown University is now offering several FELLOWSHIPS in the DEPARTMENT OF PHYSICS to qualified graduates of recognized Colleges, Universities, and Technical Schools.

These Fellowships are open only to candidates for the Master's Degree, and appointments will be made for the period of one year,

with the possibility of renewal for an additional year upon evidences of high scholastic achievement on the part of the holder.

The stipend is $600.00 a year in addition to exemption from tuition, but not from other fees.

One or two appointments are to be made beginning with the Summer Session (July 6—September 29, 1942), and one beginning with the Winter Session, which opens October 5, 1942.

HOLY CROSS COLLEGE—CHEMISTRY DEPT.
FACULTY TALKS AT CLARK UNIVERSITY

November 5, 1941. Vapor Phase Nitration. Pro. Edwin T. Mitchell.
December 3, 1941. Natural Pigments. Prof. Oliver L. Baril.
February 25, 1942. The Vitreous State. Rev. Joseph J. Sullivan, S.J.

GLASS BLOWING SEMINARS
1941—1942

December 1, 1941. The Vitreous State. Clifton R. Largess, B.S. '42.
December 15, 1941. Glass. Charles J. McNulty, B.S. '43.
January 12, 1942. Plate Glass. Peter P. Salatiello, B.S. '43.
January 19, 1942. Glass Bricks. Andrea V. Vaccarelli, B.S. '42.
February 9, 1942. Fiber Glass. Charles A. Polachi, B.S. '43.
February 16, 1942. Laminated Glass. Charles W. Chagnon, B.S. '43.
March 2, 1942. Laminated Plastics. John J. Killoran, B.S. '42.
March 9, 1942. China. Michael D. Riordan, B.S. '43.
March 16, 1942. Porcelain. Robert E. Kiely, B.S. '43.
March 23, 1942. Plastics. John P. Loughman, B.S. '43.
March 30, 1942. Modern Stained Glass. John P. Hardiman, B.S. '42.
April 13, 1942. Ceramics. John A. Green, B.S. '42.

GLASS BLOWING ASSIGNMENTS

1. Burette tips.
2. Straight seal. a) tubes same diameter. b) tubes different diameter.
3. Bends. 3 different angles. U tube.
4. Bulbs. a) bulb on end of tube. b) bulb in middle of tube.
5. T and Y tubes.
6. Internal seals. (RING SEALS).
7. Closed circuit.
8. Hempel tube. No. 1328.
9. $CaCl_2$ tube. Nos. 2722, 2723.
10. $CaCl_2$ tube. No. 2727.
11. Connecting tube. No. 3532.
12. Mercury valve. No. 3895.
13. Culture flask, Pasteur. No. 4372.
14. Distilling tube, 2 bulb. No. 4720.
15. Electrode vessel. No. 4869.
16. Glass trap for ammonia, Folin. No. 3530.
17. Blood collector, Vacuum, Noguchi. No. 3638.

18. Absorption bulb Midvale. No. 3850.
19. Ampoules. No. 1070.
20. Mercury pipette. No. 8231.
21. Test tubes. No. 9444.
22. Syphon, Glass. No. 9738.
23. Thistle tube. No. 5646.
24. Leveling bulb. No. 5953.
25. Adapters. Nos. 1008, 1009.
26. $CaCl_2$ tube. No. 2726.
27. Pipette, Indicator. Nos. 3798, 3813A.
28. Culture tube, Gates. No. 4373.
29. Distilling tube. No. 4717.
30. Filter tube. No. 5310.
31. Filter tube. No. 5311.
32. Pipette, Mercury. No. 8231.
33. Culture flask, Gates. No. 4363.
34. Filter pump. No. 5284.
35. Claisen flask. No. 5411.
36. Knorr extraction flask. No. 4950.
37. Filter flask. Nos. 5430, 5431.
38. Pipette. No. 6101.
39. Kjeldahl bulb. Nos. 7500, 7501, 7502.
40. Potash bulb. No. 8450.
41. Specific gravity bottle. Nos. 9030, 9026.
42. Sulfur apparatus. No. 9324.

N. B. Nos. refer to Arthur H. Thomas Catalogue. Copy in Glass Blowing Laboratory.

LOYOLA COLLEGE—DEPT. OF PHYSICS

With the increasing demand for war courses in subjects such as Meteorology, Radio, Navigation, etc., the question of continuing the regular program in Physics for advanced students was submitted to the class toward the end of the first semester, and a vote was taken with explanation for the vote in the final examinations. The result turned out thirteen votes for continuing according to schedule in Modern Physics, eleven for a course in Meteorology. Later in consultation with some of the better students a satisfactory compromise was reached, two hours per week instead of the usual three in Modern Physics, with the third hour given to a course in Meteorology. Laboratory work will be assigned according to each individual student's interest.

LOYOLA COLLEGE—DEPT. OF MATHEMATICS

To assure credit in College Mathematics for Juniors and Seniors lacking these credits and aspiring to appointments as ensigns, two large classes have been organized in this subject for the second semester, an ambitious undertaking on the part of students and a really war-time load on the faculty.